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EXAMINER REPORT

Candidate's name: Varun Kumar Ojha

Degree to be awarded: PhD degree

Thesis title: Feature Selection and Function Approximation Using
                             Adaptive Algorithms

General comments and assessment

The thesis developed by Mr. Varun Kumar Ojha presents research investigations in the general area of machine learning, with the specific aim to develop more effective techniques for feature selection and model identification (function approximation).

Overall, in my opinion, the research described in this thesis is at an appropriate level for a doctoral degree, where several original contributions and results were put forward. In addition to the presented contributions, there is very clear evidence that the candidate has broad knowledge in the field of computational intelligence and is very well capable to apply sound scientific methods.

The structure of the thesis is very good, with the content of the thesis adequately balanced among the 6 chapters of the thesis. The writing style and language used in the thesis is very good in general, although some small language and editorial mistakes can be found across the thesis, but which do not affect too much the quality of the presentation.

The main research contribution of the thesis lies in a number of investigations which led to the development of two novel methods presented in Chapters 3 and 5, respectively.

The first contribution is an original method, called the Heteregeneous Flexible Neural Tree (HFNT), which is a tree-like model where nodes are heterogeneous neural network nodes, and the model can adapt its structure, inputs, weights and

activations functions. A multi-objective genetic programming approach (MOGP) was used to guide an initial population of such HFNTs towards the Pareto-optimal front, and then several diverse Pareto-optimal solutions are selected to form an ensemble. Differential evolution is also used to fine-tune the parameters of the HFNTs during the learning process. The proposed method was first applied to a number of popular classification, regression and time-series benchmark datasets. Then, the HFNT proposed method was successfully used in a real-world pharmaceutical problem to predict the die filling performance of pharmaceutical granules.

The second contribution of the thesis is a novel multi-objective genetic programming (MOGP) based method for learning a hierarchical fuzzy inference tree (HFIT). As with the previous proposed method, structure optimization (using MOGP) and the parameter tuning (using differential evolution) is repeated until the optimal HFIT is obtained. Variants (using type-1/type-2 and single/multi-objective optimization) of the proposed method to learn HFITs were successfully applied to learn several benchmark datasets and then to a challenging real-world prediction problem from the pharmaceutical industry.

Both proposed approaches were compared against existing methods in the literature and were shown to outperform many of them.

The candidate demonstrates an excellent understanding of the relevant literature in the broad area of computational intelligence, with particular focus on recent evolutionary optimization as well fuzzy and neural network approaches. Chapter 2 provides an excellent up-to-date review in the field. The list of references is comprehensive for the purpose of this thesis and contains relevant and recent papers.

The candidate has already published several papers on the results and contributions of the thesis in refereed journals and conference proceedings in the area. The number of publications is well above the typical number of publications for a PhD student and a few of these papers are published in some of the best venues in the field. This shows that the research work undertaken as part of this PhD research has been already assessed by peers.

In conclusion, I confirm that Varun Kumar Ojha's thesis is of sufficient substance and quality, and **<u>I therefore recommend that the PhD degree be awarded</u>**.
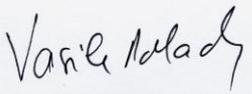
List of minor editorial and typographical errors that are suggested to be corrected before the thesis is sent to library (This is just a list of several small editorial changes and it does not amount to "thesis accepted subject to minor changes"):

1. Some of the titles sound better in a plural form: "1.2.1. Feedforward neural networks", "1.2.2 Fuzzy inference systems", "2. Metaheuristic design of feedforward neural networks", "2.2. Feedforward neural networks", "2.3 Metaheuristic approaches", "3.3.2 Heterogeneous flexible neural trees", "4.

Metaheuristic design of fuzzy inference systems", "4.2 "Fuzzy inference systems", "4.2.1. Components of FISs".

2. Other titles should be slightly reformulated: "3.3 Multiobjectives for flexible neural trees (or better - Multiobjective optimization of flexible neural trees)", "3.3.1 Pareto-based multiobjective optimization", "3.6. Performance of HFNT on benchmark datasets", "4.3.5. Multiobjective strategies ("farmworker" sounds bad) for FIS tuning", "5.2. Multiobjective optimization of fuzzy inference trees".

3. The thesis is well written in general. However, it would be good if the thesis is proof-read again before it is sent to library to eliminate all the typographical and small language mistakes. An annotated thesis highlighting such mistakes will be given to the candidate after the viva.

Yours Sincerely,   **19th September 2016**

Coventry University, UK